Novel MCz-silicon material and application for the radiation detection community
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12th Trento Workshop – February 22nd 2017
Content

- Okmetic
- Advanced-MCz
- Okmetic Applications
Okmetic: leading supplier of high-performance silicon wafers

<table>
<thead>
<tr>
<th>Key figures</th>
<th>2016</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net sales</td>
<td>75.7 MEUR</td>
</tr>
<tr>
<td>Operating profit*</td>
<td>7.9% of net sales</td>
</tr>
<tr>
<td>Personnel</td>
<td>377</td>
</tr>
</tbody>
</table>

* 2016 are preliminary and have not yet been approved by the Board or audited by an external auditor.

Vantaa plant, Finland
- Crystal growing
- Discrete&Analog wafers: 150-200 mm
- Sensor wafers: 100-200 mm
- SOI wafers 100-200 mm
- Capacity: 250 kpcs/month

Fab lite capacity
- Umesato, Japan
- Ferrotec, Shanghai
- GlobalWafers / SST, Shanghai
- GlobalWafers, Japan
- Capacity: 300 kpcs/month
Silicon wafers for 100 – 200 mm volume manufacturing

Wafer platforms:
• SSP (single side polished) wafers
• DSP (double side polished) wafers
• SOI (Silicon-On-Insulator) wafers, large product family

Application examples:
• MCz-NTD wafers for IGBT manufacturing
• High resistivity wafers up to and beyond 5 kOhm cm
• Low resistivity wafers below 1 mOhm cm
• Silicon substrates for GaN applications

Complete set of 100-200 mm wafers for Sensor and Discrete&Analog markets
Okmetic’s Magnetic Czochralski Silicon

MCz advantages

- Enables high resistivity by lower Oxygen concentration compared to standard Cz
- Availability of large diameter and <111> oriented ingot
- Better slip resistance and mechanical properties compared to FZ
- Radiation tolerance compared to FZ
# Ultra low $O_i$-MCz for high resistivity wafers

<table>
<thead>
<tr>
<th>MCz: p-type resistivities up to 5000 $\Omega$cm</th>
<th>Advanced MCz: resistivity up to 10000 $\Omega$cm and beyond</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Improved thermal stability of resistivity compared to regular Cz</td>
<td>• New level of resistivity for MCz</td>
</tr>
<tr>
<td>• Thermal donor generation creates challenge for some sensor fabrication processes</td>
<td>• Still better slip resistance and radiation hardness compared to FZ</td>
</tr>
<tr>
<td></td>
<td>• Thermal donor generation largely suppressed</td>
</tr>
<tr>
<td></td>
<td>• Enables completely new designs and capabilities for device designers</td>
</tr>
</tbody>
</table>
Oxygen in High Resistivity Silicon – Resistivity Control

- High Resistivity MCz Silicon contains oxygen
  - Coming from quartz crucible used in the crystal puller
  - > below 10 ppma for typical MCz ingots

- At elevated temperatures (T > 400 °C) Oxygen atoms become mobile and diffuses in the lattice.

- Between 400 °C < T < 500 °C the probability for dimer or oxygen cluster formation is very high

- Clusters of oxygen atoms can become electrically active → thermal donors (n type doping)
Worst-Case-Scenario: Resistivity Shift at 450 °C

TD introduction at 450 °C

Resistivity shift at 7 kΩ cm

10 ppm
5 ppm

Type inversion
FTIR Transmittance vs. $O_i$-Content

Influence of $O_i$ visible at 9 um
Low Oxygen MCz similar to FZ

Ingot resistivities:
1. High Resistivity for FZ, A-MCz and MCz
2. Cz: 1-10 $\Omega$ cm
Selecting Si-ingot material for each application

- **Standard Cz**
  - Good slip resistance and radiation hardness
  - Suitable for internal gettering
  - Good for standard and low resistivity

- **MCz**
  - Good slip resistance and radiation hardness
  - Suitable for high resistivity
  - Low Oi, Low BMD counts

- **Ultra low Oi A-MCz**
  - Better slip resistance and radiation hardness compared to FZ
  - Suitable for ultra high resistivity
  - Very low Oi. No BMDs.

- **FZ**
  - Poor slip resistance and radiation hardness
  - No BMDs.
  - Suitable for ultra high resistivity
  - High cost and limited availability especially in 200 mm
Selecting Si-ingot material for each application

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- Good slip resistance and radiation hardness
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**Optimal for HL-LHC Sensors**

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**ASTM F121-83**

<table>
<thead>
<tr>
<th>O$_i$ Concentration [ppma]</th>
<th>O$_i$ Concentration [E17 cm$^{-3}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>8</td>
<td>8</td>
</tr>
</tbody>
</table>

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Sensors from SOI Wafers

- Thin active device layers possible
- Handle wafer electrically isolated from device wafers
- Handle can be etched, ground…
- Wafers fully CMOS compatible
  → Applicable also for HV applications
Wafers with Through-Silicon Vias (TSV)

Interconnect characteristics achieved with the etched via with doped polysilicon filling:
- Capacitance of <1 pF
- Resistance of a few tens of Ohms
- Breakdown voltage in excess of 100V
- Leakage current below 5 pA@100V
Summary

Advanced MCz is a very good match for particle sensor applications
Contact us

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communications@okmetic.com
SOI Wafers (Silicon On Insulator)

- Improved electric properties
- Advanced design of sensors
Okmetic’s Bonded SOI (BSOI) Product Family

**BSOI**
Fully customizable with starting materials from in-house crystal growth and wafering

**0.3-SOI**
Improved device layer thickness tolerance ±0.3 µm

**E-SOI**
Enhanced uniformity wafers with device layer thickness tolerance ±0.1 µm

**L-SOI**
Low resistivity SOI device layers

**C-SOI**
Wafers with pre-etched cavities

**D-SOI**
Two device and buried oxide layers with different thicknesses
## Typical SOI Wafer Specifications

<table>
<thead>
<tr>
<th>Growth method:</th>
<th>Cz, MCz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal orientation:</td>
<td>&lt;100&gt;, &lt;111&gt;, &lt;110&gt;</td>
</tr>
<tr>
<td>Diameter:</td>
<td>100, 150, 200 mm</td>
</tr>
</tbody>
</table>
| Type & Dopant: | P: boron  
N: antimony, arsenic, phosphorous |
| Resistivity: | < 0.0015 to > 1000 Ohmcm |
| Thickness: | **SOI layer:**  
from 2 µm to > 200 µm,  
tolerance ±0.5µm, standard BSOI  
tolerance ±0.3µm, 0.3-SOI  
tolerance ±0.1µm, E-SOI  
**Handle wafer:**  
from 300 µm to 950 µm, typical 380 µm  
back surface polished or etched |
| Buried oxide: | Type: thermal oxide  
Thickess: from 500 nm to 4 µm |